

“Get the Heatsink Off Your Back”

A Technical White Paper by **SynQor**



Summary

The intent of this technical white paper is to demonstrate how SynQor's *PowerQor* family of synchronous rectifier based dc/dc converters provide more usable output power without a heatsink than do the conventional, Schottky diode based converters with a heatsink.



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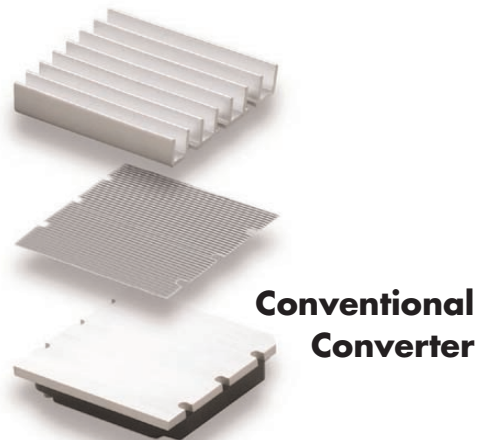


Figure 1: SynQor's *PowerQor* dc/dc converter and a conventional converter with heatsink. (not shown to scale)

Approach

First, we will study how much “heat-removal” capacity we lose when we take away a dc/dc converter's heatsink. Next, we will determine how much less heat we need to remove from SynQor's high efficiency *PowerQor* converters compared to the low efficiency, conventional converters. Finally, we will compare the power derating curves for both converters to see how the *PowerQor* converters gain more from their higher efficiency than they lose from not having a heatsink.

Starting Assumptions

For the purpose of this study, we will focus on the standard half-brick size dc/dc converter (2.3" x 2.4"). Generally, the best Schottky diode based converters of this size can deliver 150 watts or 30 amps to their outputs. This is the "rating" of the device; users can only get this level of power from the converter if they keep it cool enough. As we will see, the actual power that the converter can deliver

is usually less than this rating in a user's worst case thermal environment.

What do we Lose when we take the Heatsink Away?

The purpose of a heatsink is to increase the surface area that the cooling airflow contacts so that the thermal resistance to that air is reduced.

It is convenient to measure the effectiveness of a heatsink by comparing it to the situation where no heatsink is used. For instance, a conventional dc/dc converter that has a baseplate with no heatsink attached will have a certain thermal resistance, $R_{CA}(w/o \text{ heatsink})$, between that baseplate and the flowing air. If we then attach a heatsink to this baseplate, the new thermal resistance, $R_{CA}(\text{heatsink})$, will be smaller than $R_{CA}(w/o \text{ heatsink})$ by some factor. This factor tells us the value of the heatsink.

Ideally, if the surface area of the heatsink's fins were twice the area of the converter's baseplate, then it would reduce the thermal resistance between the baseplate and the air by a factor of two. In reality, such a one-to-one correspondence is not achieved for several reasons.

First, there is a thermal resistance associated with getting the heat from the baseplate up into the heatsink's fins. This additional resistance comes partly from the thermal pad (or thermal grease) that we place between the baseplate and the heatsink to fill the gaps, and partly from the need for the heat to flow up through the narrow fins. Second, not all of the cooling airflow makes its way into the spaces between the heatsink's fins at the same flow rate that it crosses a flat baseplate. Both of these phenomena cause the heatsink to provide less heat-removal than would be expected from its increased surface area.

The following table shows the factor of heat-removal improvement that heatsinks of various heights offer compared to having no heatsink. In this table, the definition of the improvement factor is the thermal resistance with no heatsink, $R_{CA}(w/o \text{ heatsink})$, divided by the thermal resistance with a heatsink, $R_{CA}(\text{heatsink})$.

Airflow Rate (LFM)	0	100	200	300	400	500
For 1.00" High Heatsink	2.3	2.5	2.7	2.9	3.0	3.1
For 0.75" High Heatsink	1.7	1.9	2.1	2.2	2.3	2.3
For 0.50" High Heatsink	1.4	1.6	1.7	1.8	1.8	1.8
For 0.25" High Heatsink	1.2	1.2	1.3	1.3	1.3	1.3

Table 1: Factor of improvement offered by a heatsink as a function of the heatsink height and the airflow rate. (Data taken from Lucent specification sheets.)

Notice that the improvement factor depends on the airflow rate. At the lower airflow rates, a heatsink does not offer as much improvement as it does for the higher airflow rates.

These improvement factors are what we lose in heat-removal when we take the heatsink away. To at least "stay even", therefore, we need the power dissipated by the SynQor converters to be reduced by

the same factor. The next section addresses this issue.

How much Smaller is the Heat Dissipation in the SynQor Converters?

Conventional converters use Schottky diodes to rectify the output of their transformers. The Schottky diodes dissipate most of the heat lost in these converters. SynQor's *PowerQor* line of dc/dc converters use synchronous rectifiers to rectify the output of their transformers. The synchronous rectifiers in the *PowerQor* converters greatly reduce the heat dissipation that would otherwise occur in the Schottky diodes of a conventional converter.

Table 2 compares the full load efficiency of SynQor's 30 amp *PowerQor* converters to that of conventional converters at the same load current. The right hand column of this table shows the factor by which the dc/dc converter's heat dissipation is reduced when you use the *PowerQor* converter.

From this table, we can see that the reduction in heat dissipation offered by the SynQor 30 Amp *PowerQor* converters ranges from a low of 20% for a 15Vout converter to 300% for a 1.5Vout converter. In other words, the lower the output voltage, the more painful the Schottky diodes of the conventional dc/dc converters, and the more valuable the shift to synchronous rectification.

Output Voltage	Full Load Output Current	Efficiency of Conventional Schottky Diode Converter	Efficiency of SynQor's 30A Synchronous Rectifier Converter	Reduction in Dissipated Heat Offered by SynQor's Converter
15V	10A	88%	90%	1.2
12V	12.5A	86%	90%	1.5
5V	30A	83%	89%	1.7
3.3V	30A	79%	89%	2.2
2.5V	30A	74%	87%	2.4
2.0V	30A	68%	85%	2.7
1.5V	30A	62%	83%	3.0

Table 2: Reduction in dissipated heat offered by SynQor's high efficiency dc/dc converters over conventional Schottky diode based converters

Why we need to look at the Power Derating Curves before we make Comparisons?

We now know 1) the amount of heat-removal that we give up when the heatsink is eliminated, and 2) how much the SynQor 30 Amp *PowerQor* converters reduce the amount of dissipated heat. It would seem that a simple comparison would tell us whether we gain more from the higher efficiency of a SynQor converter than we lose by getting rid of the heatsink.

A true comparison is not so simple, however. One reason is that the SynQor converter does not have a metal baseplate. Instead, it has an open-frame structure that displays several significant differences. First, it has a lower height than a conventional converter (0.4" vs. 0.5" without the heatsink) so that air will more readily pass over the SynQor converter instead of going around it. Second, its upper surface is irregular, which promotes a turbulent airflow that removes heat better than a linear airflow. Third, there is room for air to flow under the SynQor converter, which also increases the removal of heat.

A second reason that the comparison is not so simple is that a converter's efficiency is a function of both its output power and its temperature. The efficiencies listed in Table 2 are for only one combination of power and temperature: full load and 25 °C. SynQor's converters are designed to hold their high efficiency relatively constant throughout most of their power range, and this efficiency decreases only slightly as the converter gets hotter.

For these reasons, the best way to determine whether we gain more than we lose is to look directly at the power derating curves. Power derating curves show how much power a dc/dc converter can deliver as a function of the temperature and the flow rate of the ambient air. Each point on a power derating curve represents a combination of output power and environmental condition that causes the temperature of some component within the converter to reach a predetermined limit.

Manufacturers of conventional dc/dc converters specify that users should keep the baseplate of their converters below some maximum limit (typically 100 °C). Hotter ambient air, slower airflow, and shorter heatsinks all translate into less power that the user can extract from the converter before the baseplate reaches this limit.

Since the SynQor converters do not have a baseplate, we look directly at our components to tell us when we should limit the output power of the converter. We have decided that our power MOSFETs, which are rated for 150 °C operation, should not get hotter than 125 °C. In addition, we have decided that our PCB, which is rated for 130 °C, should not get hotter than 120 °C (or 110 °C near the isolation barrier). Choosing these values well below the components' actual rated temperature limits allows significant built-in margins for the derating curves. You can therefore feel more comfortable using the SynQor converter at the limits of its derating curves.

Note that for conventional converters the specification sheets do not mention how hot the components within the converters get when you let their baseplates reach 100 °C. We therefore do not know how much margin, if any, is designed into the power derating curves of these converters. If we assume the worst, we would probably like to add in some margin by not using these converters at the limits of their derating curves.

How do the Power Derating Curves Compare for 3.3 Vout Converters?

Except where specifically mentioned we derived all of the power derating curves presented in this document by making measurements on the actual dc/dc converter. To do this we set up the wind tunnel shown in Figure 2 in which we can control the temperature and the flow rate of the air. We mount the converter on a PCB within this wind tunnel and take thermal images of it through a window on the side of the tunnel. With this apparatus, we can find the exact power level at which a temperature limit is reached under a given environmental condition.

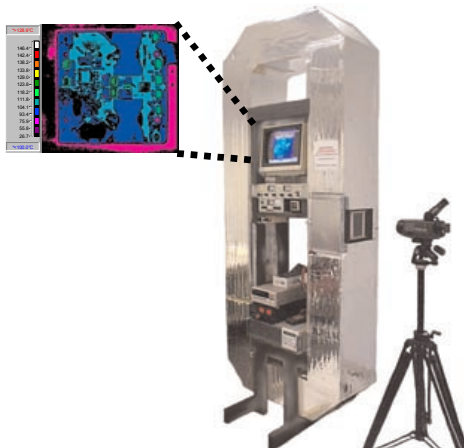
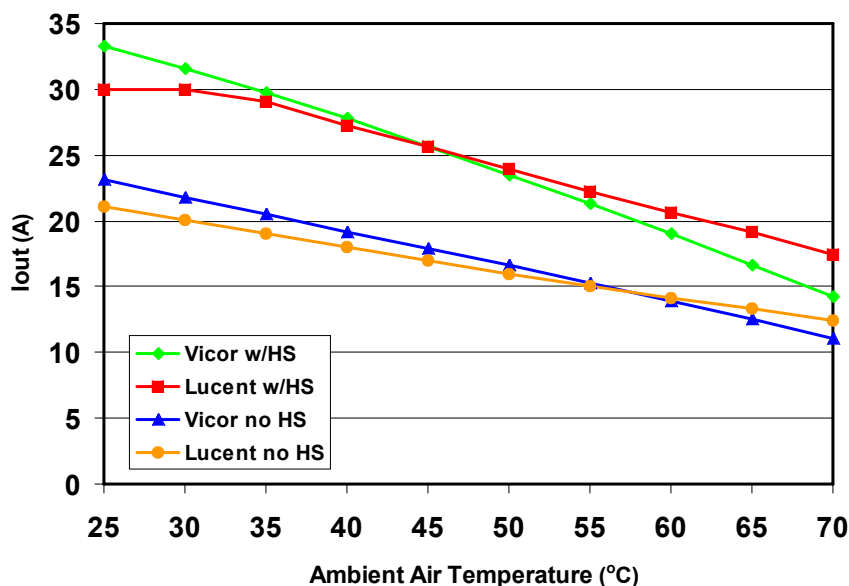


Figure 2: SynQor's wind tunnel and thermal camera which allows exact measurements of power derating points for any environmental condition.

The following graph shows the power derating curves for two brands of 3.3V output Schottky diode based converters. For each brand there are a set of curves for the situation where a 0.5" high heatsink is attached to the converter and another set of curves for the situation where no heatsink is used. A similar set of curves could be shown for other brands, other output voltages, and other heatsink heights. Some manufacturers give the user all the information they need to create these power derating curves for each of their converters; others do not.

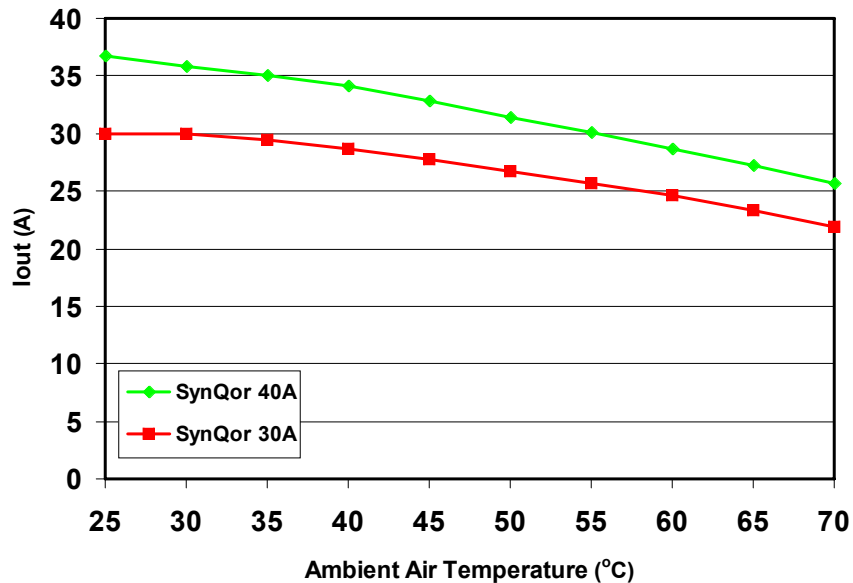


Graph 1: Power derating curves showing Lucent's JW150 and Vicor's Next Generation 3.3 Vout half-brick modules with 200 LFM of airflow with and without a 0.5" heatsink.

As you can see from these curves, the actual power you can get from a half-brick size conventional converter is less than its "rating". For instance, even with a 0.5" high heatsink, you can only draw 22

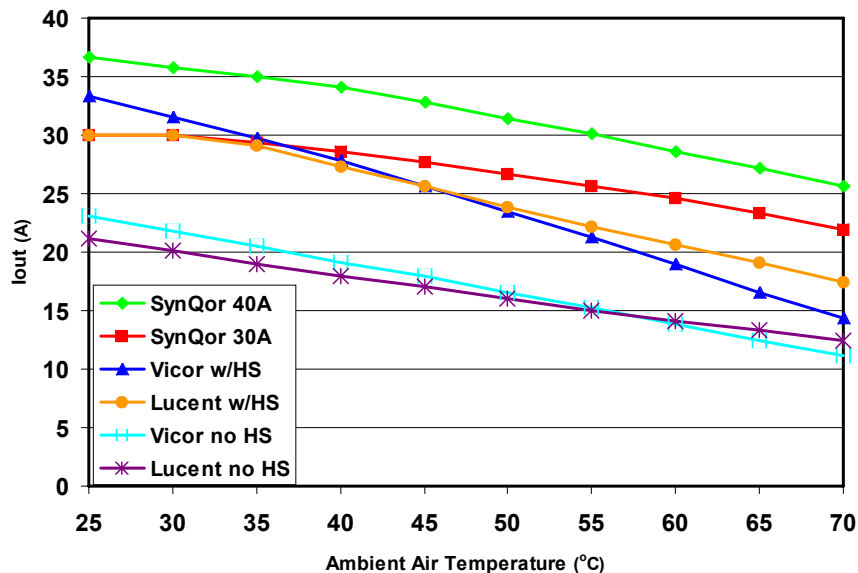
amps from the Lucent JW150 converter if your worst case environment is 55 °C and 200 LFM. If you do not have room for a heatsink, you can only draw 15 amps.

In comparison, the graph below shows the power derating curves for the *PowerQor* 3.3V 30A and 40A half-brick converters. Remember that these curves are for a converter that has no heatsink and no metal baseplate.



Graph 2: Power derating curves showing *PowerQor* 30 Amp and 40 Amp half-brick modules (3.3Vout) with 200 LFM of airflow and **no attached heatsink**.

To aid in the comparison of the derating curves shown above, the following graph puts together the 200 LFM curves from each of the previous graphs.



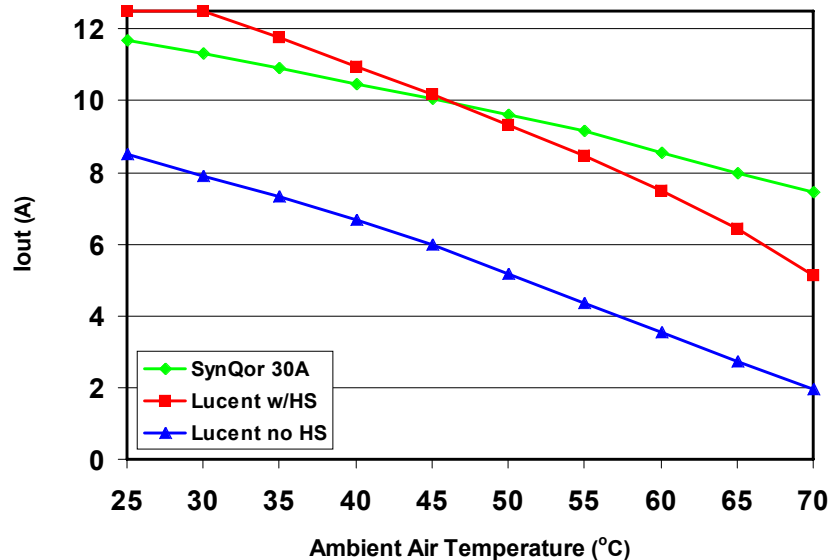
Graph 3: Power derating curves comparing all half-brick modules (3.3Vout) with 200 LFM of airflow.

As you can see, the high-efficiency SynQor 3.3Vout converters can deliver significantly more output current and power without a heatsink than the conventional 3.3Vout converters can with a 0.5" heatsink. And if you don't have room for the heatsink regardless of which converter you choose, the SynQor converters deliver substantially more power.

How do the Power Derating Curves Compare for Other Output Voltages?

What happens to this comparison as we look at converters with different output voltages other than 3.3V? Based on the efficiency levels given in the second table, we would expect that the 200 LFM power derating curves for the SynQor converters (without heatsinks) and the conventional converters (with heatsinks) will get closer together for voltages higher than 3.3V. This is because at the higher output voltages the efficiency level of a Schottky diode based converter is much better than at the lower output voltages. On the other hand, we would expect the SynQor converters to look relatively better for the lower output voltages where the conventional converters have very low efficiency levels. The following graphs will provide the exact data we need to make our comparisons.

First, let's look at the higher output voltages. The graph below shows the 200 LFM power derating curves for **12Vout** converters from SynQor (no heatsink) and Lucent (with and without 1/2" high heatsink).

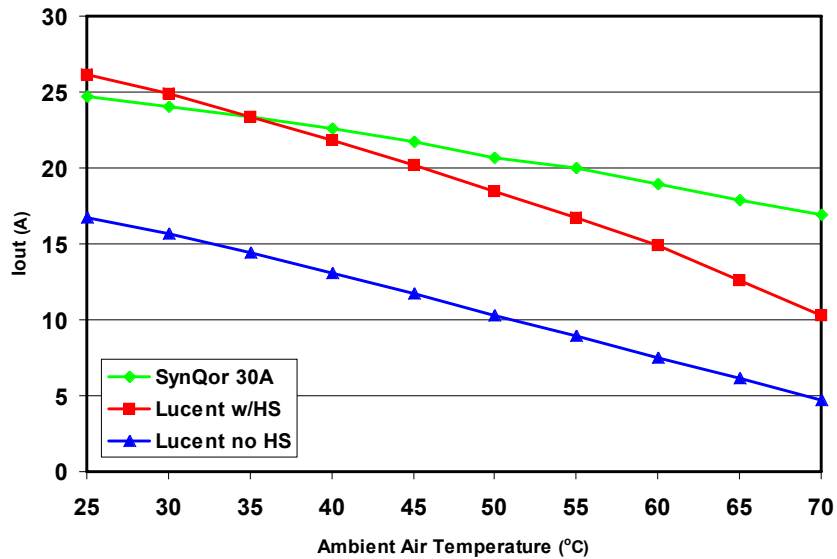


Graph 4: Power derating curves comparing **12 Vout** Lucent and SynQor half-brick modules with 200 LFM of airflow. (Derived from data on Lucent's specification sheet).

As you can see, the SynQor converter outperforms the Lucent converter with heatsink when the ambient air temperature exceeds 45°C. At 55°C, the SynQor converter delivers over 7% more output current than the Lucent converter with a heatsink.

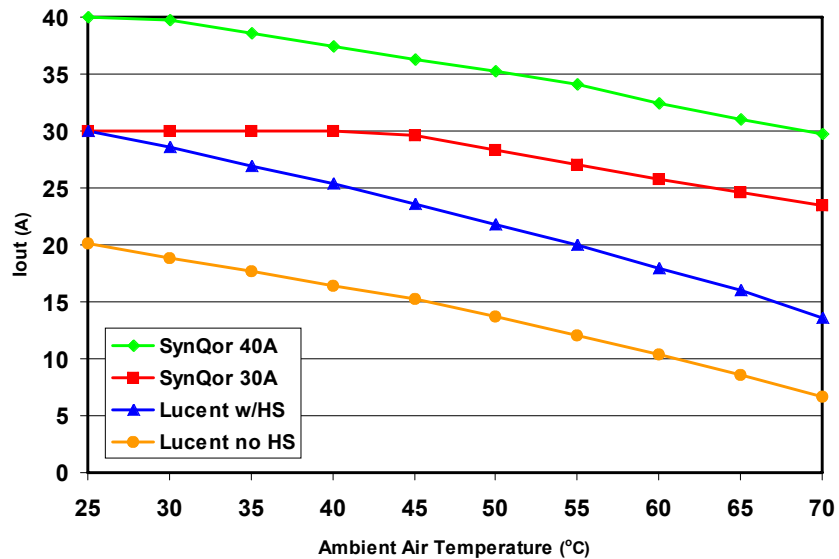
Graph 5 shows the 200 LFM power derating curves for **5.0 Vout** converters from SynQor (no heatsink) and Lucent (with and without 1/2" high heatsink). In this case the SynQor converter provides

more output current for any temperature above 35°C. At 55°C, the SynQor converter delivers about 20% more output current than the Lucent converter with a heatsink



Graph 5: Power derating curves comparing **5.0 Vout** Lucent and SynQor half-brick modules with 200 LFM of airflow. (Derived from data on Lucent’s specification sheet).

Now let’s see what happens when the output voltage is lower than 3.3V. Graph 6 shows the 200 LFM power derating curves for both the 30A and 40A **2.5 Vout** converters from SynQor (no heatsink) and Lucent’s 30A converter (with and without 1/2” high heatsink).



Graph 6: Power derating curves comparing **2.5 Vout** Lucent and SynQor half-brick modules with 200 LFM of airflow. (Derived from data on Lucent’s specification sheet).

For this lower voltage, the SynQor converters deliver substantially more output current under all thermal conditions. At 55°C, the SynQor 30A converter delivers 35% more output current while the 40A converter provides 70% more current than the Lucent converter with a 0.5" heatsink.

Conclusions

The data presented in this paper shows that dc/dc converter technology has taken an evolutionary leap forward. By using synchronous rectification and an improved design, the SynQor converters can provide impressive gains in efficiency, especially at the lower output voltages. As a result, the PowerQor converters dissipate less than 1/2 the heat of conventional converters for the low output voltages of today's logic circuits. This allows the converters to operate with no attached heatsink or baseplate, which reduces the height, weight, cost and application effort over a converter with a heatsink. The SynQor converters can also deliver significantly more output power than comparable converters with heatsinks. By using a no-heatsink converter, you can "Get the Heatsink off your Back" and begin to reap the advantages of higher efficiency and improved thermal performance.



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